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DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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MAGAZINES AND THAW HOUSES FOR EXPLOSIVES

BY

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MAGAZINES AND THAW HOUSES FOR EXPLOSIVES.

BY CLARENCE HALL AND SPENCER P. HOWELL.

INTRODUCTION.

The application of explosives to the arts of peace has received a tremendous impetus in recent years, and to-day by far the largest proportion of the explosives manufactured in this country is used in engineering and mining work. Explosives have facilitated the driving of tunnels, the building of roads and railways, the winning of ores and coal, the removal of obstructions to navigation, and the rapid accomplishment of many tasks that would have been impossible without their use, except by an enormous expenditure of time and money.

The Bureau of Mines, in its investigations of the causes of mine explosions, has given attention to the more important problems involved in the efficient and safe use of explosives in mines. This paper supplements the directions for storing and thawing explosives given in Bulletin 17.^a

STORAGE AND HANDLING OF EXPLOSIVES.

In order that the demands of the users of explosives may be promptly supplied, it is necessary that manufacturers, transporters, distributors, and users of explosives maintain proper and adequate storage facilities. The necessity therefore arises of having magazines in which may be stored large quantities of explosives. At high temperatures explosives may become unstable and more sensitive to shock or frictional impact; consequently they should be stored in cool places. As the addition of moisture is deleterious to all explosives, it is undesirable to store any explosive in a damp place. Hence, in order that correct conditions may prevail, explosives should be stored in a thoroughly ventilated magazine situated on well-drained ground. Since any change in composition may affect the safety or the efficiency of an explosive, explosives containing a definite quantity of moisture should not be subjected to a drying-out process.

The placing of a magazine in relation to ground level affects two safety features in opposite ways. When the magazine is above

^a Munroe, C. E., and Hall, Clarence, A primer on explosives for coal miners, 1911, pp. 29-32 and 61-66.

ground, adequate drainage is easily maintained, but any natural or artificial barricade for limiting the effect of possible explosions is less effective. When the magazine is partly or wholly below the surface of the ground, barricades are more effective, and for some magazines the earth itself would be an adequate barricade. However, such construction may make proper drainage difficult or even impossible, and drainage should be given first consideration.

A certain magazine in eastern Pennsylvania is placed in the ground in a hole such that the top of the magazine is below the ground level, but as the ground slopes from the magazine, proper drainage is easily obtained by means of a large pipe. Entrance to the magazine is effected by means of steps leading down from the ground level to the drainage level.

PROTECTION OF EXPLOSIVES IN MAGAZINES.

During storage explosives should be protected as far as practicable against heat, moisture, fire, lightning, projectiles, and theft. The buildings should therefore be weatherproof, covered by fireproof and bullet-proof material, well ventilated, in secluded locations, and not exposed to fire risk from burning grass or underbrush.

Detonators or other devices containing fulminating composition should not be kept in a magazine in which there are explosives. For storing such devices a small building at a safe distance from the magazine should be provided.

RECEIVING EXPLOSIVES.

A trustworthy person should have supervision of the receiving and storing of explosives in magazines. He alone should have access to the magazines for the purpose of taking out explosives that are required for immediate use.

When a new consignment of explosives is received, it should be stored in the magazine in such a way that the oldest explosives can be issued first. When storing the packages in a magazine a space of a few inches between the walls and the packages should be left for ventilation purposes. The boxes should not be placed so that the cartridges stand on their ends, because this position increases the exudation or leakage of nitroglycerin from cartridges of nitroglycerin explosives.

OPENING PACKAGES.

Packages of explosives should never be opened within the magazine, but in a properly sheltered place at a safe distance from the magazine. They should be opened with a wooden mallet and a wooden wedge. If a screwdriver is necessary in opening boxes, it

should be used only for removing screws. Packages of explosives should never be opened with a nail puller, nor powder kegs with a pick.

REPAIR AND CARE OF MAGAZINES.

When it is necessary to repair or make alterations in a magazine all explosives should be carefully removed and the magazine thoroughly washed. All tools used in making repairs should be of wood or brass. The driving of nails into the floors of old buildings that have been used in the manufacture of explosives has resulted in serious accidents.

Magazines should be kept clean and the floors should be kept free from grit or dirt. The ground around the magazine should be kept free from rubbish, leaves, and dead grass, and from other materials that might feed a fire. A warning somewhat like the following should be conspicuously posted: "Explosives—dangerous—no shooting allowed."

No artificial heat of any kind for thawing or other purposes should be introduced into a magazine. As stated elsewhere, explosives may become unstable and are more sensitive to shock when stored at high temperatures. When thawing is necessary, the explosives necessary for immediate use should be taken away from the magazine and thawed in a manner described hereafter.

BULLET-PROOF MAGAZINES.

In the United States, especially in the Western States where the hunting of wild game is general, bullet-proof magazines are essential. Accordingly the light-construction type can not be recommended.

In an investigation of the most suitable materials for magazine construction the authors tested fireproof materials in a finely divided state to determine the resistance such materials may offer to the penetration of rifle bullets. It was assumed that the materials could be used as a filling between thin boards that would act as a form and remain as part of the permanent structure. Sand has been used in constructions of this kind, but its most objectionable feature is that it eventually flows out through the cracks of the form on the floor of the magazine. Any gritty material of this kind on the floor is obviously a menace to safety. Mineral wool has also been suggested as a suitable bullet-resisting material, but has been found to have little value, as indicated by the test results listed below.

TESTS OF BULLET-PROOFING MATERIAL.

Sand versus mineral-wool filling.—Tests were made to determine the depth to which bullets penetrate into fine sand and into mineral

wool. The sand used was pure Lake Michigan dune sand of 30 to 80 mesh fineness. The mineral wool was packed tight in the partition. Both minerals were placed between two 1-inch boards $11\frac{1}{2}$ inches apart. Three series of tests with various firearms were made with each material, as follows:

Penetration of bullets into sand and mineral wool.

Firearm and bullet.	Distance.	Penetration. ^a	
		Sand.	Mineral wool.
Springfield rifle, model of 1903, caliber .30; Frankford Arsenal steel-jacketed bullet or equal.	Feet. 55	Inches. 5½	11½+
		7	11½+
		7	11½+
		7	11½+
		7½	11½+
Average of 5 shots.....		6.80	11.5+
Factor of safety ^b		.88	Less than 0.52
Smith and Wesson revolver, caliber .32; ordinary lead bullet.....	25	0	-
		0	7
		0	11
		6	4
		.....	5
Average of 4 shots.....		1.50	6.75
Factor of safety ^b		4.00	.89
Springfield rifle, model of 1884, caliber .45 (70 grains of powder); ordinary lead bullet.	55	9	11½+
		10	11½+
		8	11½+
		10	11½+
		8	11½+
Average of 5 shots.....		9.00	11.5+
Factor of safety ^b		.67	Less than 0.52.

^a Thickness of wall, $11\frac{1}{2}$ inches.

^b Computed on basis of a 6-inch wall.

Sand-cement mortar filling.—With a view to overcoming certain objectionable features in the use of sand as a bullet-proofing material tests were made of a mixture of sand and a small proportion of Portland cement. Lean cement mortar so composed crumbles readily under a blow, yet retains its form if protected from the weather.

Tests were made with cement mortar and with concrete of composition as follows: Cement mortar, 73 days old, consisting of one part cement to six parts coarse sand; cement mortar, 69 days old, consisting of one part cement to six parts coarse Allegheny River sand; concrete consisting of one part cement, three parts coarse Allegheny River sand, and five parts Allegheny River gravel. Both the cement mortar and the concrete blocks were made in 1-inch board forms 24 by 24 by $11\frac{1}{2}$ inches, and the boards were left on when the tests were made. The results of the tests are tabulated below:

Penetration tests of bullets into cement mortar and concrete.

Firearm and bullet.	Distance.	Penetration. ^a		
		Cement mortar 73 days old.	Cement mortar 69 days old.	Concrete 69 days old.
	<i>Feet.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
Springfield rifle, model of 1903, caliber .30; Frankford Arsenal steel-jacketed bullet, or equal.	55	3 2½ 2½ 3 2½	.....	.....
Average of 5 shots.....		2.75	.....	.....
Factor of safety ^b		2.18	.....	.....
Smith & Wesson revolver, caliber .32; ordinary lead bullet.....	25	¼ ¼ ¼ ¼ ¼	.....	.....
Average of 5 shots.....		0.25	.....	.....
Factor of safety ^b		24.00	.....	.....
Springfield rifle, model of 1884, caliber .45 (70 grains of powder); ordinary lead bullet.	55	1 1½ 1½ 1 1½	.....	.....
Average of 5 shots.....		.90	.....	.....
Factor of safety ^b		6.67	.....	.....
Winchester rifle, self-loading, model of 1910, caliber .401, metal patched bullets.	55	.....	2 2½ 1½ 2 2	1 1½ 1 1½ ½
Average of 5 shots.....		.....	2.00	1.00
Factor of safety ^b.....		.....	3.00	6.00
Winchester rifle, self-loading, model of 1910, caliber .401, soft-point lead bullet.	55	.....	2 1½ 2 2 2	1 ¾ 1½ 1½ 1
Average of 5 shots.....		.....	1.95	1.25
Factor of safety ^b.....		.....	3.08	4.80

^a Thickness of wall, 11½ inches.^b Computed on basis of a 6-inch wall.

A comparison of the relative penetration of bullets in sand, mineral wool, and cement mortar shows that cement mortar offers the greatest resistance; also with this material no strong retaining walls are necessary. Although concrete offers greater resistance to the penetration of bullets than does cement mortar, its use can not be commended because of the probability that an explosion would project large blocks of concrete.

LIGHTNING CONDUCTORS.

In England there is a statutory requirement that all magazines shall be provided with a lightning conductor, but no definite arrangement of the conductors is prescribed. In other countries a metallic network is suspended above the magazine on metal poles, the poles

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being placed in a circle 20 to 30 feet distant from the magazine. At some magazines the network is dispensed with, the poles alone being depended on for protection against lightning.

The practice in Germany is to support vertical copper rods of high electrical capacity near the magazine. The rods are from 36 to 80 feet high, and are sometimes placed on the embankment.

As stated elsewhere, the entire roof and all sides of the Bureau of Mines magazine are covered with galvanized sheet iron, and the iron portions are grounded with $\frac{1}{2}$ -inch iron rods extending from the four lower corners of the building, the ends of the rods being buried below the moisture line and being attached to a properly laid earth plate. The rods also serve as excellent mediums for silently reducing the potential between the earth and the clouds. Where water mains or running streams are available, good practice allows the grounds to be properly attached to or in them. If, as the result of an unusual electric discharge, any part of the galvanized-iron cover should be burned or melted, the explosives would be protected from fire by the 6-inch walls of nonconducting cement mortar.

PROTECTION OF LIFE AND ADJACENT PROPERTY.

The most important consideration in the storage of explosives is the prevention of explosions. If this is accomplished no damage to life and property can result. Since absolute prevention is impossible, certain precautions must be taken to prevent damage should an explosion occur. These are discussed below.

SELECTION OF MAGAZINE SITE.

In selecting a site for a magazine the topography of the ground should be carefully considered, and advantage should be taken of any natural protection offered by hills. It is preferable to erect a magazine on sandy soil rather than on rocky ground, for, in the event of an explosion, the distance which the earth waves are transmitted is materially reduced when the explosion occurs on loose and friable ground. The distance separating magazines from inhabited dwellings and railways should be far enough so that if an accidental explosion occurs within a magazine the least possible damage will be done to the buildings of the surrounding country. The laws in foreign countries require that between magazines and inhabited dwellings there shall be certain distances, depending on the quantity of explosives stored, the natural or artificial protection provided, and the attitude of the inhabitants of the neighborhood.

REGULATIONS IN UNITED STATES GOVERNING ISOLATION OF MAGAZINES.

Massachusetts regulations.—The State of Massachusetts has enacted regulations governing the isolation of magazines. Table A gives the prescribed distance that a magazine shall be separated from

a public railway, highway, public promenade or open place of resort for the public, or public freight wharf or pier. The table also shows the maximum amount of explosives allowed in a magazine according to its location.

TABLE A.—*Storage of explosives in Massachusetts.*

Allowed quantity.	Separating distance.	Allowed quantity.	Separating distance.
<i>Pounds.</i>	<i>Feet.</i>	<i>Pounds.</i>	<i>Feet.</i>
50	99	3,000	630
100	150	4,000	645
200	225	5,000	675
300	255	10,000	795
400	285	20,000	990
500	300	30,000	1,035
600	330	40,000	1,380
700	360	50,000	1,575
800	390	60,000	1,770
900	420	70,000	1,965
1,000	450	80,000	2,160
1,500	510	90,000	2,355
2,000	555	100,000	2,550

Table B gives the prescribed distance that a magazine must be separated from a dwelling house, factory, church or chapel, university, college or school hospital, public institution, city or town hall, court of justice, covered market, theater, passenger wharf, railway station, or any other building where people are accustomed to assemble. The table also shows the maximum amount of explosives allowed in the magazine according to its location.

TABLE B.—*Storage of explosives in Massachusetts.*

Allowed quantity.	Separating distance.	Allowed quantity.	Separating distance.
<i>Pounds.</i>	<i>Feet.</i>	<i>Pounds.</i>	<i>Feet.</i>
50	270	3,000	1,416
100	351	4,000	1,566
200	453	5,000	1,716
300	504	10,000	2,166
400	555	20,000	3,012
500	606	30,000	3,858
600	657	40,000	4,704
700	708	50,000	5,550
800	756	60,000	6,540
900	810	70,000	7,530
1,000	861	80,000	8,520
1,500	1,116	90,000	9,510
2,000	1,266	100,000	10,500

American Railway Association regulations.—The regulations of the American Railway Association were summarized in Bulletin 17^a of the Bureau of Mines, as follows:

In June, 1909, the chief inspector of the bureau of explosives of the American Railway Association brought to the attention of the manufacturers of explosives in the United States the dangers that attend the location of storage

^a A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall, 1911, pp. 64–65.

magazines too near to railway property, and invited a conference to discuss the steps that should be taken to remove these dangers.

A committee was appointed by the manufacturers to make an exhaustive study of all the data that could be collected the world over showing the damage that had resulted from explosions. As had been anticipated, much difficulty was experienced in getting reliable information in regard to such damage. The committee finally succeeded in collecting more or less reliable information relating to over 130 explosions. From these data, curves were platted on a large scale to show for the quantity of explosives involved the maximum distances at which structural damage to buildings had resulted from the explosions. The term structural damage covers injury to foundations, to supporting walls (exterior or interior), or to roof or floor members; it does not include the breaking of glass or the shaking down of plaster.

From experience gained principally at manufacturing plants, it was concluded that an effective artificial barricade surrounding a magazine, or the intervention of a natural obstacle screening the property to be protected, would result in reducing by 50 per cent the necessary maximum distance observed in connection with unprotected magazines. In studying the data collected, therefore, the curves were platted on the assumption that the magazine was thus barricaded or protected. With the exception of two or three instances, concerning which there was reasonable doubt of the reliability of the data collected, the curves were drawn to pass outside of all the platted points showing structural damage. From these curves the accompanying table was prepared to show the distances that, according to the quantity of explosives involved, should separate storage magazines from inhabited dwellings and from railways. For any such magazine not protected by an efficient barricade, or by a natural safeguard, the distance should be doubled.

Proposed minimum distances between barricaded magazines and railways or inhabited dwellings.

Quantity of explosives stored.	Proposed distance.		Quantity of explosives stored.	Proposed distance.	
	Inhabited building.	Public railway.		Inhabited building.	Public railway.
<i>Pounds.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Pounds.</i>	<i>Feet.</i>	<i>Feet.</i>
50	120	70	10,000	890	535
100	180	110	20,000	1,055	635
200	260	155	30,000	1,205	725
300	320	190	40,000	1,340	805
400	360	215	50,000	1,460	875
500	400	240	60,000	1,565	940
600	430	260	70,000	1,655	995
700	460	275	80,000	1,730	1,040
800	490	295	90,000	1,790	1,075
900	510	305	100,000	1,835	1,100
1,000	530	320	200,000	2,095	1,255
1,500	600	360	300,000	2,335	1,400
2,000	650	390	400,000	2,555	1,535
3,000	710	425	500,000	2,755	1,655
4,000	750	450	600,000	2,935	1,760
5,000	780	470	700,000	3,095	1,855
6,000	805	485	800,000	3,235	1,940
7,000	830	500	900,000	3,355	2,015
8,000	850	510	1,000,000	3,455	2,075
9,000	870	520			

It should be understood that the proposed distances given in the above table have not yet been sanctioned by law. Whenever it becomes necessary, however, for a court to decide what is a reasonable distance in a locality where such a distance is not specified by law,

common practice requires resort to the testimony of experts. The above table gives the results of an investigation of prominent experts and represents their combined judgment reached after an honest and prolonged study of all available data. Presumably, therefore, the table will be accepted as a guide, and any person maintaining a storage magazine at distances less than those prescribed by it will be subject to successful prosecution before the courts for the maintenance of a public nuisance. All interested parties will therefore act wisely if at the earliest possible moment they make sure that their magazines are located in accordance with the above table. However, in any locality where the law on this subject is now specific the law must, of course, be the guide.

REGULATIONS IN EUROPEAN COUNTRIES GOVERNING ISOLATION OF MAGAZINES.

Austrian regulations.—Magazines are required to be of light construction so that in the event of an explosion the danger from flying débris is reduced to a minimum. On the other hand, little protection against unlawful entry or penetration by rifle bullets is afforded. Storage regulations are divided into two classes, as follows:

Class I embraces regulations covering the following: All factory buildings which do not belong to the explosives factory; buildings the owners of which have given their permission in writing; and roadways and streets which are not much frequented.

Class II embraces regulations governing the following: All inhabited dwellings and endangered buildings, shops, and factories, railroads and waterways not covered in Class I; national, county, and municipal highways and roads which are much frequented; and, in general, all objects an accident to which is liable to have serious consequences.

Sales magazines which are to contain more than 6 pounds of explosives are never permitted to be erected in an inhabited locality. The location of such magazines is determined by the public authorities of the district after the commission has investigated the matter as regards the capacity of the magazine and its distance from the nearest protected works.^a The following regulations must govern:

(a) Sales magazines for 6 to 220 pounds of explosives must be at a distance of at least 328 feet from all protected works enumerated in Classes I and II.

(b) Magazines for 221 to 1,102 pounds of explosives must be not less than 656 feet from the nearest protected works belonging to Class I and not less than 1,640 feet from those belonging to Class II.

(c) Magazines for 1,103 to 2,204 pounds of explosives must be not less than 984 feet from protected works belonging to Class I and not less than 3,280 feet from those belonging to Class II.

^a The words "protected works" are intended to include all structures, railroads, highways, and waterways.

(d) Magazines for 2,205 to 22,046 pounds of explosives must be not less than 1,640 feet from the protected works belonging to Class I and not less than 3,280 feet from those belonging to Class II.

English regulations.—The English table of distances was prepared by His Majesty's inspectors of explosives who had collected and digested extensive data relating to injury and damage done by explosives. The table is given below :

English table of distances for the isolation of magazines.

Quantity of explosives to be stored.	Distances that must intervene between nonbarricaded magazine and—	
	Public railway.	Dwelling house, theater, etc.
Pounds.	Feet.	Feet.
500	.....	300
1,000	.....	450
2,000	.....	600
3,000	630	720
4,000	645	740
5,000	675	960
6,000	705	1,095
7,000	720	1,215
8,000	750	1,335
9,000	765	1,455
10,000	795	1,575
20,000	990	2,550
30,000	1,185	3,600
40,000	1,380	4,575
50,000	1,575	5,550
60,000	1,770	6,525
70,000	1,965	7,500
80,000	2,160	8,550
90,000	2,355	9,525
100,000	2,550	10,500

When the protected work ^a is effectively screened from the magazine, either by the natural features of the ground or by good and substantial artificial mounds of earth or mine refuse of such height that a line drawn from any part of the magazine to any part of the protected work will pass through the intervening ground or mound, the required distance (except for quantities of 1,000 pounds and under) from that protected work is reduced by one-half; provided that when a natural hill so intervenes as to afford a degree of protection that in the opinion of a Government inspector justifies a further reduction, the distance shown in the table is reduced to one-quarter.

The English table of distances, as modified above, furnishes the basis on which applications for licenses are considered, but it is subject to modification under special circumstances.

Italian regulations.—Under Italian regulations permanent store-houses or magazines that are to contain more than 440.92 pounds of explosives and are for the purpose of selling explosives or for sup-

^a See footnote on p. 13.

plying the requirements of continuous or varied work must be isolated and licensed by competent authorities. A license to open a magazine of this kind is subject to the following conditions regarding the location of the magazine:

The minimum distance, in direct line, from the magazine itself to inhabited places, public streets, etc., may differ under varying conditions, the distances under these varying conditions being shown in the tabulation below:

Italian table of distances for the isolation of magazines.

[Italian weights and measures converted into pounds and feet.^a]

Quantity of explosives to be stored in one magazine.	National, provincial, and municipal streets, railways, navigable rivers and canals.	Inhabited dwellings and private property.	Factories, large groups of houses, churches open to worship, and national monuments.	Boroughs or cities having a population of—		
				500 to 5,000.	5,001 to 10,000.	More than 10,000.
Pounds.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
440 to 1,102.....	164	229. 60	328	492	656	656
1,103 to 2,204.....	244	328	492	656	820	984
2,205 to 9,920.....	328	574	820	984	1,148	1,312
9,921 to 22,046.....	328	656	984	1,640	1,640	2,624
22,047 to 44,092.....	328	984	1,312	3,280	4,920	6,560
44,093 to 88,184.....	492	1,640	2,296	4,920	6,560	8,200
88,185 to 176,368.....	574	1,640	3,280	6,560	8,200	9,840

^a The distances given in the second, third, and fourth columns may be reduced one-half in special cases. It is lawful to establish in the same locality under the same title two or more magazines containing 176,368 pounds, if the magazines are surrounded by barricades, if the distance between the magazines is not less than 328 feet, and if for each the distances established by the table are observed.

Prussian regulations.—In Prussia the prescribed distances of magazines from buildings and workshops are as follows:

1. The distance of the magazine from dwellings and workshops, railways, and public highways is to be determined in each case separately in accordance with the existing conditions. If the magazine is to be situated in a free and unprotected place, the following distances from other buildings, railways, and public highways are generally required:

330 feet for magazines containing not more than 330 pounds of explosives.

495 feet for magazines containing from 331 to 1,100 pounds of explosives.

999 feet for magazines containing more than 1,100 pounds of explosives.

2. If a magazine is properly protected by natural conditions such that the top of the protecting mound is at least 1 meter wide, or by artificial embankments consisting of at least one barricade reaching to the roof of the magazine, the distances may be reduced.

Regulations in other countries.—In France, Belgium, and other European countries there are no laws specifying the maximum quantity of explosives permitted to be stored in any one magazine. Before authorization is granted for the erection of a magazine a special commission determines, in accordance with the merits of each case, the

maximum quantity which may be stored in the magazine. The decision of the commission depends upon the conditions as a whole, the manner in which the magazines are protected, as well as the situation and structure of property to be protected.

COMBINED TABLE OF DISTANCES.

A combined table of distances showing for certain quantities of explosives stored the minimum lawful distance (where known) that a magazine may be located from inhabited structures is given below. The proposed American distances are made to apply to nonbarricaded magazines, in order that a comparison with the distances of other countries may be readily made. The Austrian, Italian, and Prussian distances in the table seemingly do not discriminate as to the allowable distances at which widely different quantities of explosives may be stored, but this seeming oversight is a result of the particular quantities used in the illustration and the fact that any given allowable distance is applicable to a larger range of quantity.

Combined table of distances for the isolation of magazines from inhabited structures.

Quantity of explosives stored.		Barricaded magazine.	Nonbarricaded magazine.					
		Proposed American distances.	Proposed American distances.	Massachu- setts distances.	Austrian distances.	English distances.	Italian distances.	Prussian distances.
<i>Pounds.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
50	120	240	270	328	328	300	230	330
100	180	360	351	328	328	300	230	330
500	400	800	606	1,640	1,640	450	230	495
1,000	530	1,060	861	1,640	1,640	450	230	495
5,000	780	1,560	1,716	3,280	3,280	960	574	999
10,000	890	1,780	2,166	3,280	3,280	1,575	656	999
50,000	1,460	2,920	5,550	5,550	5,550	1,640	1,640	1,640
100,000	1,835	3,670	10,500	10,500	10,500	1,640	1,640	1,640
500,000	2,755	5,510	.....	.....	.....	.....	.....	.....
1,000,000	3,455	6,910	.....	.....	.....	.....	.....	.....

BARRICADES.

In nearly all foreign countries mounds or artificial barricades are used in connection with magazines having no natural protection. The mounds are constructed of earth or sand, and in the construction care is taken not to use large stones or other material that might be projected in large masses in the event of an explosion. The mounds are usually 3 feet higher than the highest point of the roof. They are usually 3 feet wide at the top, with a natural slope on both sides, the inner slope reaching within a few feet of the sides of the building. Where such mounds are used, the distances required between magazines and dwellings are materially less.

In connection with the storage of any large quantity of explosives, barricades should always be erected if there is not sufficient natural protection. Any side or sides of a magazine in line with any dwelling, shaft, or railway should be guarded with mounds of more substantial construction.

CONSTRUCTION OF MAGAZINES.

The construction of magazines differs materially, many of them being substantial structures built of concrete, brick, or large blocks of stone. These materials are objectionable in the event of an explosion within a magazine. More frequently magazines are built of a light framework of wood covered with corrugated iron, and no attempt is made to protect the explosives against the penetration of rifle bullets.

UNITED STATES.

At the request of Col. B. W. Dunn, chief inspector of the bureau of explosives of the American Railway Association, studies and investigations were undertaken by the Bureau of Mines to determine the most suitable materials for the construction of magazines.

The first investigation undertaken aimed to find a suitable material that could be used economically and that would be effective in resisting the penetration of rifle bullets. The results of the investigation are given on page 9 of this paper.

DISINTEGRATION TESTS ON CEMENT-MORTAR BLOCKS.

Because of the danger arising from the use of concrete or solid masonry for the construction of magazines, tests were conducted to find a material that would shatter easily and at the same time produce a building sufficiently substantial to meet all requirements. Following is a description of the procedure and the results of the tests:

Sixteen $\frac{3}{4}$ by 8 inch cartridges of 40 per cent nitroglycerin dynamite, having an average weight of 111 grams, were placed as in the sketch (fig. 1) on a 24 by 24 by 6 inch block of cement mortar, made of 1 part cement and 6 parts of coarse sand, the mortar being 75 days old. The block was placed in a horizontal position and supported by two 2-inch pieces of gas pipe. Four No. 6 electric detonators connected in series were used to detonate the charge and were placed as indicated by the small circles in figure 1. The paper ends of the cartridges were cut off before they were placed on the block.

The pieces resulting from the explosion were screened, with the results shown in the accompanying table. The dimensions of the screens represent the inside dimensions of their square opening. The

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material passing through the $\frac{1}{4}$ -inch screen was thoroughly disintegrated to sand and cement dust.

Screening test of disintegrated cement-mortar block.

Size of material.	Pounds.	Per cent.
Caught on $1\frac{1}{2}$ -inch screen.....	5 $\frac{1}{2}$	2
Caught on $\frac{3}{4}$ -inch screen, through $1\frac{1}{2}$ -inch screen.....	4	2
Caught on $\frac{1}{4}$ -inch screen, through $\frac{3}{4}$ -inch screen.....	12 $\frac{1}{2}$	6
Through $\frac{1}{4}$ -inch screen.....	205	90
	226 $\frac{1}{2}$	100

The results of the test clearly indicate that in the event of an explosion in or near a magazine constructed of cement mortar, the mortar would not be projected in large masses over the surrounding

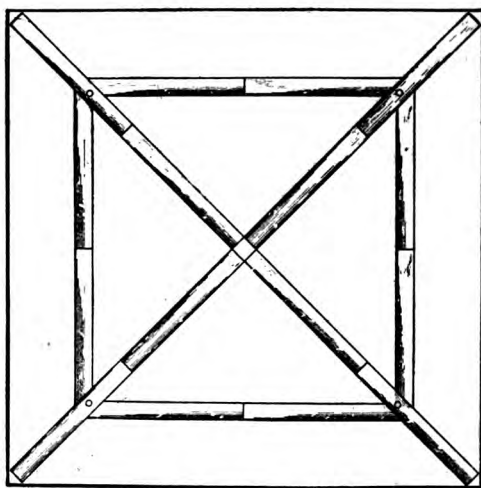


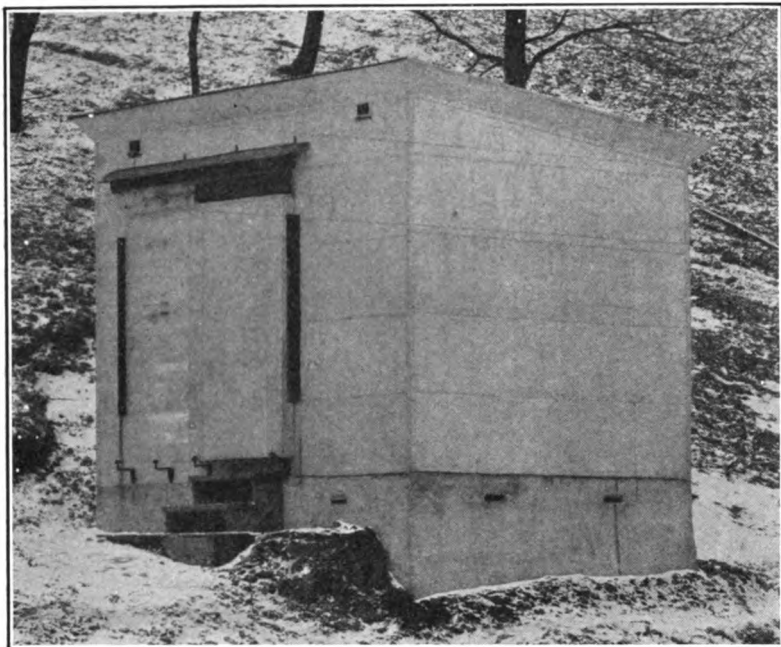
FIGURE 1.—Arrangement of cartridges on cement-mortar block.

country. On the other hand there is a record of an explosion of the explosives stored in a concrete building having six compartments; in that explosion blocks of concrete weighing as much as 1,000 pounds were projected 700 or 800 yards.

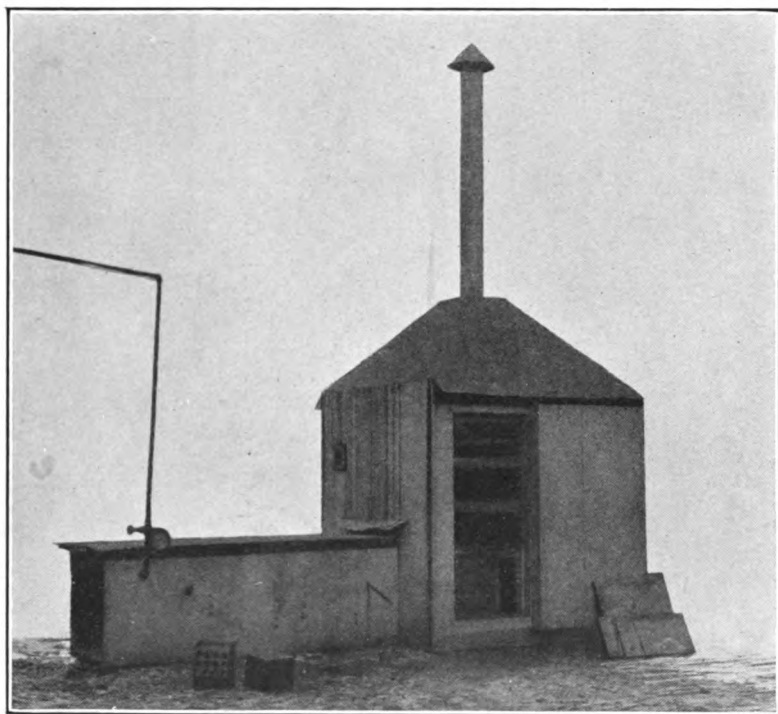
BUREAU OF MINES MAGAZINE.

As a result of experiments and of information furnished by the manufacturers of explosives, a cement-mortar magazine (Pl. I, A, and fig. 2) has been erected by the Bureau of Mines. The magazine has a capacity of 20,000 to 30,000 pounds of explosives, and was built at a cost of \$400. The outside dimensions are 10 by 14 feet.

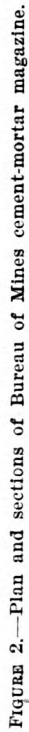
The salient features of the magazine are the cement-mortar walls, sliding door, and roof. The cement mortar is 6 inches thick in all walls and 3 inches thick in the roof and the door. The door is secured



A. BUREAU OF MINES CEMENT-MORTAR MAGAZINE.



B. BUREAU OF MINES CEMENT-MORTAR THAW HOUSE.



by two substantial locks. No metal of any kind is exposed on the inside of the magazine. The ventilators above the floor are arranged to prevent the entrance of bullets or firebrands.

The means provided for ventilation have been found to be adequate, and, accordingly, the storage conditions are favorable for keeping the explosives from deteriorating. The cement-mortar construction is effective in resisting the penetration of rifle bullets, and because of its friable nature offers an additional advantage for the reason that, in the event of an explosion in or near the magazine, large masses of material will not be projected over the surrounding country. The galvanized-iron covering is fire resisting; it also serves as an excellent medium for protection against lightning, as the four corners of the building are properly grounded with metal rods.

In order that the details of construction may be thoroughly understood, the following bill of materials is presented. The concrete of the foundation consists of one part cement, three parts sand, and five parts gravel. The cement-mortar in the walls, door, and roof consists of one part cement to six parts coarse sand.

BILL OF MATERIALS.

Lumber.

1 piece of yellow pine, 2 inches by 6 inches by 18 feet.
 1 piece of yellow pine, 6 inches by 8 inches by 14 feet.
 11 pieces of yellow pine, 2 inches by 10 inches by 10 feet.
 2 pieces of yellow pine, 1 inch by 3 inches by 12 feet.
 4 pieces of yellow pine, 2 inches by 10 inches by 10 feet.
 8 pieces of yellow pine, 2 inches by 6 inches by 14 feet.
 9 pieces of yellow pine, 2 inches by 8 inches by 10 feet.
 6 pieces of yellow pine, 2 inches by 4 inches by 7 feet.
 6 pieces of yellow pine, 2 inches by 4 inches by 8 feet.
 2 pieces of yellow pine, 4 inches by 4 inches by 7 feet.
 2 pieces of yellow pine, 4 inches by 4 inches by 8 feet.
 24 pieces of yellow pine, 2 inches by 4 inches by 9 feet.
 3 pieces of yellow pine, 2 inches by 4 inches by 14 feet.
 9 pieces of hemlock, 1 inch by 10 inches by 10 feet.
 8 pieces of hemlock, 1 inch by 10 inches by 12 feet.
 15 pieces of hemlock, 1 inch by 10 inches by 14 feet.
 28 pieces of hemlock, 1 inch by 10 inches by 16 feet.
 400 feet of lumber for framework of foundation.
 48 board feet of 16-foot No. 2 white-pine flooring.
 856 board feet of No. 2 yellow-pine flooring, consisting of 19 bundles 16 feet long, 1 bundle 14 feet long, and 11 bundles 10 feet long.

Hardware.

100 pounds of 8d. wire nails.
 40 pounds of 20d. wire nails.
 4 pieces of iron, $\frac{3}{8}$ inch by $1\frac{1}{4}$ inches by 7 feet.
 2 pieces of iron, $\frac{3}{8}$ inch by $1\frac{1}{4}$ inches by 18 inches.

- 2 pieces of angle iron 3 inches by 5 feet long.
- 2 pairs of No. 130 Coburn trolley hangers.
- 8 feet of No. 4 track.
- 2 end brackets.
- 1 center bracket.
- 1 heavy iron door handle.
- 4 brackets with hardwood rollers.
- 500 square feet of No. 26 gage galvanized flat iron.
- 150 square feet of galvanized corrugated iron.
- 2 pieces of 5-inch by 8-inch, $\frac{3}{4}$ -inch mesh, No. 6 wire screen.
- 8 pieces of 4-inch by 10-inch, $\frac{3}{4}$ -inch mesh, No. 6 wire screen.

Cement, Sand, and Gravel.

- 80 bags of cement.
- 200 bushels of sand.
- 150 bushels of gravel.

ENGLAND AND GERMANY.

Magazines in England are generally substantial buildings with masonry or heavy brick walls, for the reason that the danger of explosion within a magazine is considered to come mostly from without. The buildings are constructed with a view to protecting contents from rifle bullets and from unlawful entry, lightning, and fire. The objectionable feature of this type of magazine is that in the event of an explosion within the magazine, large fragments of the heavy walls are projected over the surrounding country, endangering life and property in the vicinity.

In Germany many of the magazines are substantially constructed; others are of light wooden construction. Reinforced concrete construction has been recently adopted in buildings of this kind. In 1911 the Carbonite Explosives Co. (Ltd.), constructed at Schlebusch, Germany, 10 gravel-cement magazines, each having a capacity of 33,000 to 44,000 pounds. The gravel cement was made in the proportions of three parts cement to two parts gravel, no sand being used. This particular construction was adopted after two tests with a concrete magazine,^a the tests being made on the shooting grounds of Kümmersdorf in 1897. The tests indicated that no large pieces are projected by an explosion; the gravel cement was stated to be thoroughly disintegrated. The amount of gelatin dynamite used in the two tests was 3,300 and 1,100 pounds, respectively.

Figure 3 shows the substantial construction of such a magazine as that mentioned above. The figure also shows the ventilating system and the method of covering the magazine with earth. The reinforcement in the magazine is said to be a thin iron network, a construction that permits the use of thin walls. The earth covering adds

^a Bichel, C. E., Innovation in the establishment of explosives factories: Proc. Seventh Inter. Cong. Applied Chem., sec. 3-B, Explosives, 1909, pp. 48-53.

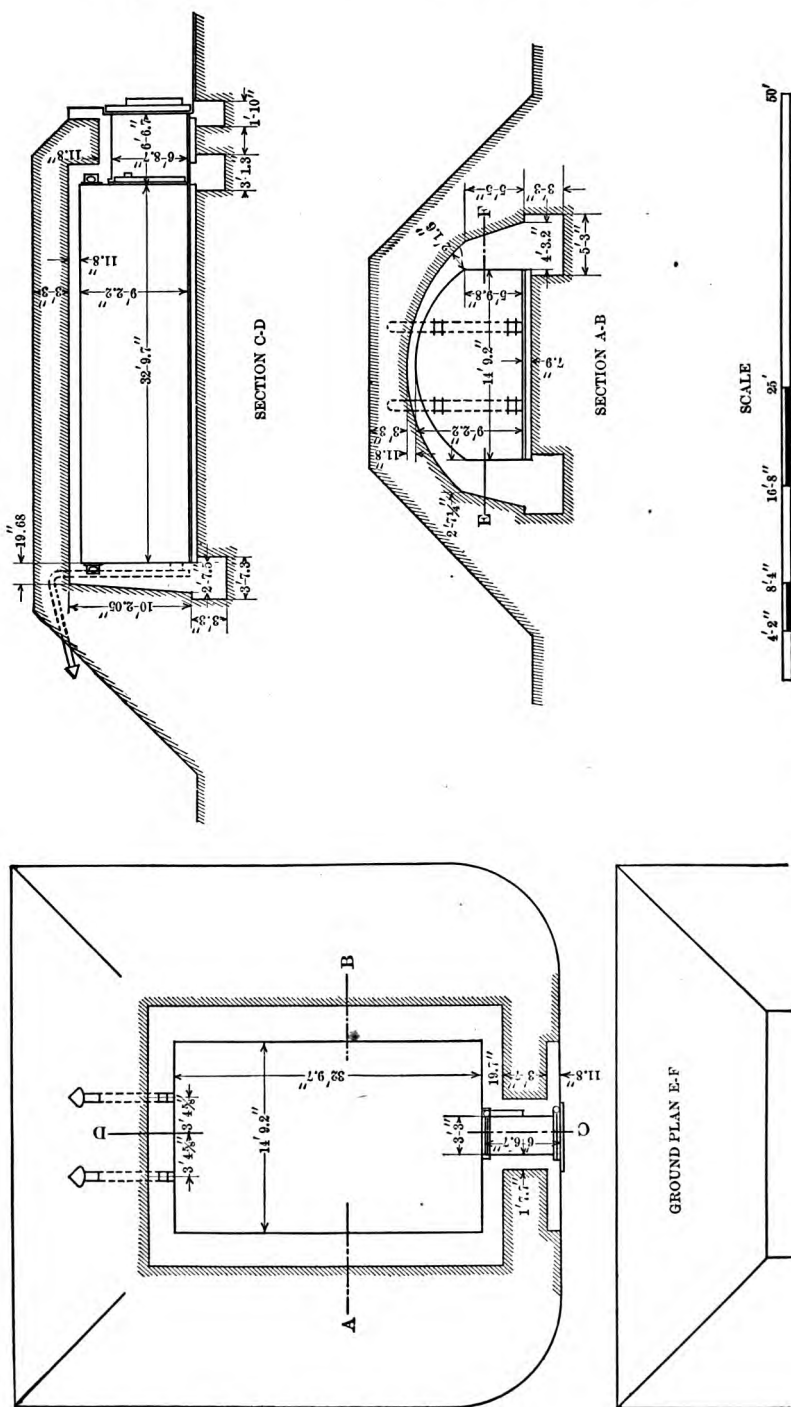


FIGURE 3.—Plan and sections of magazine of Carbonite Explosives Co.

an additional protection against flying débris. The magazines are 131 feet apart, center line to center line. They are in two rows of five each, and are staggered.

THAWING EXPLOSIVES.

When a temperature of 52° F. or less prevails, the nitroglycerin in ordinary dynamites crystallizes, or, as is commonly stated, freezes. In order to use such explosives safely and to procure the maximum efficiency they must be properly thawed before using. While being thawed, the explosives should be in a horizontal position, as otherwise they are more liable to exude nitroglycerin.

SMALL QUANTITIES.

The thawing of frozen explosives requires extreme care, and an improper method has frequently led to very serious accidents. No attempt should be made to thaw a frozen explosive by placing the cartridge before a fire, or near a boiler, or on steam pipes, or in hot water, or in the sunlight. While being thawed, nitroglycerin explosives are extremely sensitive and should be handled with great care. During thawing nitroglycerin tends to separate from the dope and run out of the cartridge (that is, to exude), and this is a source of danger.

When only a small amount of the explosive is required, it may be thawed in a thawer such as is furnished by all manufacturers of explosives and has been found safe for use as directed. Such a thawer is shown at the left of the foreground in Plate I, *B*. It consists of a water-jacketed tin vessel, in which the cartridges are placed, closed with a tin cover. Before the water is placed in the vessel it is warmed to a temperature not uncomfortable to the immersed hand; the temperature should never exceed 130° F. The cartridges are allowed to remain in the thawer until gentle pressure shows that they are completely thawed throughout. When thawed, the material feels plastic, or like flour, between the fingers. When frozen, or partly frozen, it feels more or less rigid and hard. The stick should be thawed completely, because dynamite when frozen can be detonated only with great difficulty, and any part that is frozen will be imperfectly detonated in the blasting hole; hence not only may such partly frozen powder fail to give its full effect as an explosive, but there is danger of a serious accident in a coal mine where the explosive is used; if a blown-out shot results, the burning solid part may set fire to dust or fire damp in the air of the mine.

When explosives are used in temporary commercial projects in quantities that do not require the thawing of more than 200 pounds at one time, use is often made of manure thawing boxes. They are

simple in construction, consisting of tight boxes which, after the explosives are inserted, are completely surrounded with 12 to 18 inches of fresh manure. Such thawing boxes have the advantage of cheapness, but they are adapted to the thawing of explosives only when the explosives are not needed in a comparatively short time.

The practice of placing cartridges of explosives directly in manure piles can not be recommended, for the cartridges may absorb moisture; moreover, manure may become as hot as 150° F., a temperature that is unsafe for the thawing of any explosive.

LARGE QUANTITIES.

Where large quantities of explosives are used daily a thaw house situated at a safe distance from magazines and other buildings should be provided. The capacity of the thaw house should be limited so that it will not hold more than is necessary for one shift. It should never hold more than 500 pounds of explosives. The best practice is to place in the thaw house the amount of explosive that is required for immediate use only. It is not a safe practice to expose explosives to continuous heating, as some explosives, such as gelatin dynamites, have been known to decompose and explode when subjected to high temperatures for only a few days.

LOCATION OF THAW HOUSES OR MAGAZINES.

Thaw houses or magazines should never be installed within a coal mine. In several of the metal mines in the northern part of this country where extremely low temperatures prevail in winter it has been found necessary to locate thaw houses within the mines. The thaw houses are usually placed in an abandoned or worked-out place in the mine in one of the upper levels. Thaw houses so located have been heated by electricity, a cluster of incandescent globes or a series of resistance coils being used. Many such thaw houses have the source of heat directly under the explosives, and many accidents have resulted as a consequence. Other thaw houses situated in mines have had a thin sheet of galvanized iron interposed to prevent explosives from coming in contact with the electric coils, but nearly all of them lack the proper means of control to keep the temperature under a safe limit, so that the explosives become too hot for safety.

TRANSPORTING THAWED EXPLOSIVES.

When an explosive is used in mines or quarries situated in extremely cold localities it may be transported to the working place from the thaw house in an insulated container of the required size, which is provided with a jacket of a good nonconducting material such as hair felt. A device of this kind prevents the thawed ex-

plosives from freezing during transportation. It accordingly insures the greatest efficiency in their use.

MANURE THAW HOUSES.

For explosives employed in temporary commercial projects in quantities that require the thawing of more than 200 pounds at one time, manure thaw houses have been satisfactorily used. The principle of their construction is similar to that of manure thawing boxes, except that the cartridges of explosives are placed in layers on shelves. This arrangement compensates for the reduced area of radiation per unit of volume of the inner compartment. In manure thaw houses also a door must be provided for entering the compartment. The roof and the lower portion of the exterior retaining walls should be so constructed that they are easily removable, in order that fresh manure may be added when necessary.

As the heat generated by manure is produced by chemical reaction, obviously manure will be effective as a thawing material as long as this reaction is sufficiently maintained. Such a condition often obtains for many weeks. The possible high temperature within the manure walls of the thaw house or the thawing box are not considered dangerous because the explosive within the compartment is isolated from the manure. Although careful search has been made, no instance of fire resulting from the natural heat of manure used in thaw houses or thaw boxes has been found.

CONSTRUCTION OF THAW HOUSES.

What has been said of the construction of magazines applies equally to the designing of thaw houses. In addition to protecting thaw houses from dangers from without, the increased sensitiveness of explosives within the thaw house involves another danger, due to the high temperatures that must be maintained.

Thaw houses are usually situated so as to be convenient to the shaft, pit mouth, or place where the explosives are being used, and consequently should be constructed of material that would not be projected in large pieces should an accidental explosion occur. It is also essential that thaw houses be bullet proof, and protected from lightning, unlawful entry, and fire.

In constructing thaw houses some source of heat that can be kept within safe limits must be introduced. Low-pressure steam is usually available and when used at pressures not exceeding 3 pounds, in a manner herein described, it has been found to be effective and one of the safest means of thawing explosives. The temperature of the air entering a compartment should never exceed 130° F., and a lower temperature is desirable if a temperature of 90° F. can be maintained within the thaw house.

BUREAU OF MINES THAW HOUSE.

The cement-mortar thaw house (Pl. I, *B*, and figs. 4 and 5) recently built by the Bureau of Mines for thawing large quantities of explosives has a capacity of 500 pounds and cost complete \$200. It was erected after a consideration of the various details involved, is not of prohibitive cost, and offers the following advantages:

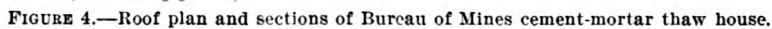
The cement-mortar walls, roof, and doors protect the explosives from bullets; the cement-mortar and galvanized-iron covering are fire resisting, and the latter furnishes a good conductor for lightning; the building is substantial; entrance is difficult and is unnecessary, for the trays can be entirely removed without anyone entering the house (see Pl. I, *B*); all parts of the house are accessible for cleaning; the explosives can be distributed in thin layers in the trays; the thermometers are easily read from without.

The thaw house of the Bureau of Mines also offers the following advantages in regard to temperature: No high temperature from artificial sources of heat obtains in the vicinity of the thaw house; the low-pressure steam, hot-water, or electric coils are not in the thaw house proper but in a separate compartment at its side, and hence particles of explosives can not come in contact with them; the explosives are not subjected to the evil effects of free steam or water; the temperature is surely and easily controlled with little attention; the entrance of cool air or the escape of heat from the thaw house is reduced to a minimum; the stack makes possible the positive circulation of heated air.

The operation of the Bureau of Mines thaw house is as follows:

The position of the heating box with reference to the explosives compartments, the slanting roof of the heating box, and the stack make a natural draft easy. The cold air from without is drawn through the air regulator, over the hot coils, through the damper opening, into the air conduit. Thence it is passed upwards through the holes in the compartment regulators and through them only. The air is then deflected to each side of each compartment by means of deflector boards, one of which is directly above each compartment regulator. As the trays in each compartment are staggered, the air is deflected backward and forward as it rises, until it finally escapes through the stack.

The air regulator consists of five adjustable three-fourths-inch louver boards, spaced 3 inches apart. This regulator is used only to control the quantity of air passing over the coils. If the outside air is very cold the quantity of air is reduced by partly closing the louver boards, in order that the air entering the explosive compartments may be heated to the proper temperature. On the other hand, when the outside temperature is comparatively high, say 32° F., the



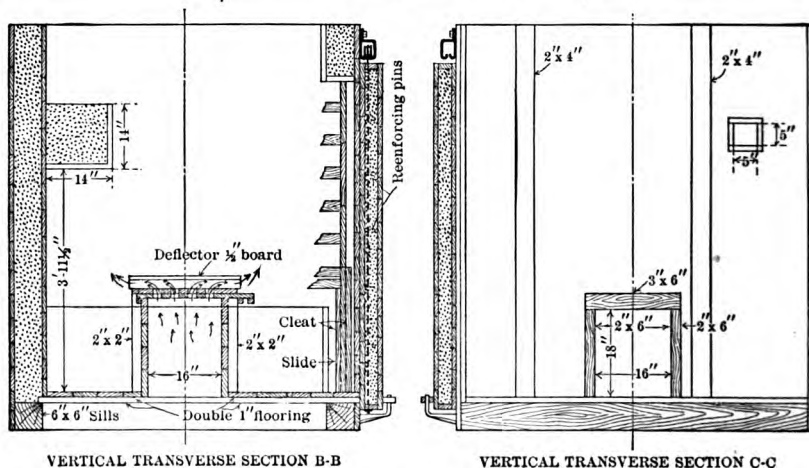
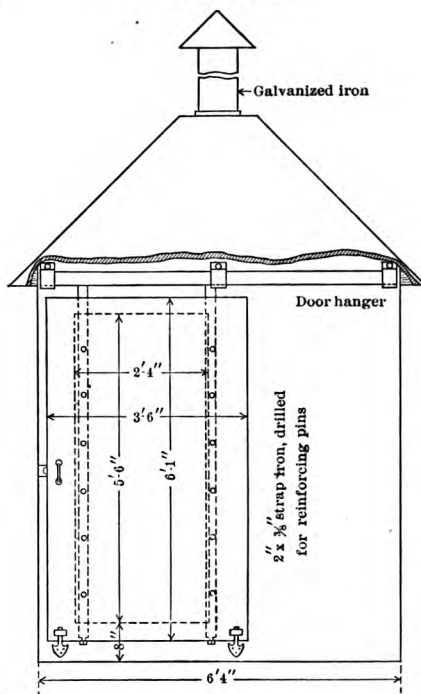
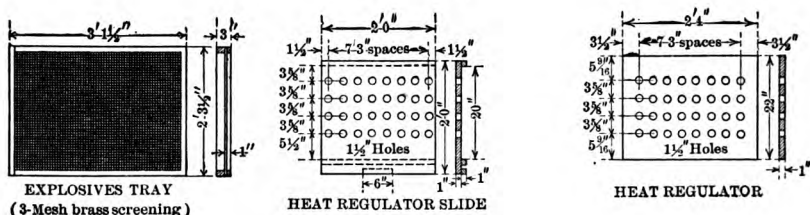


FIGURE 5.—Elevation and details of Bureau of Mines cement-mortar thaw house.

louver boards are left completely open, or nearly so, in order that the air entering the explosives compartments may not become too warm for the safe thawing of explosives.

A damper is included in the construction as a precautionary device for instantly cutting off the heating box from the air conduit and the explosives compartments.

Each compartment regulator consists of two 1-inch boards, the upper one stationary, the lower one sliding. Each board has 32 $1\frac{1}{2}$ -inch holes, the holes in the movable board coinciding with those in the upper board. Each explosives compartment may then be supplied with equal quantities of air by partly closing the holes of the regulator for that compartment. Either compartment may be completely isolated from the incoming warm air by closing its air regulator, and hence one compartment may be used without the necessity of heating the other compartment, or the compartments may be used alternately. The steam coils consist of 50 lengths of 1-inch pipe, each 5 feet 2 inches long.

TEST OF THAW HOUSE.

In order to determine the efficiency of the bureau's thaw house, a thawing test was made, the procedure being as follows:

The steam-inlet line was equipped with a valve and a steam gage on the outlet side of the valve. The steam was allowed to enter the coils at a pressure not exceeding 1 pound. Frozen "high" explosives weighing 500 pounds were placed in the thaw house, 250 pounds being placed on the trays in each of the two compartments (see Pl. I, *B*). The cartridges of explosives were laid closely side by side. In some of the trays, the cartridges were placed in three layers. The test then proceeded according to the tabulation and notes following. In explanation of the tabulation the following details are mentioned:

"W" represents the temperature at the usual position, just inside the observation window (see Pl. I, *B*) in the compartment near the heating box.

"E" represents the temperature at the usual position in the other compartment.

"O" represents the outside temperature.

1 represents the temperature of the air at the edge of the deflector board as it enters the explosives compartment near the heating box.

5 represents the temperature at a similar position in the other compartment.

2 represents the temperature at a position 18 inches above place of 1.

6 represents the temperature at a position 18 inches above place of 5.

3 represents the temperature at a position 14 inches above place of 2.

7 represents the temperature at a position 14 inches above place of 6.
4 represents the temperature of the air as it leaves the heating box.

Results of temperature test of thaw house.

Time.	O	4	W	1	2	3	E	5	6	7
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
<i>a. m.</i>										
9.30.....	16	111	87.5	100	95	88	87.5	100	97	91
10.30.....	19	149	40	54	28	31	57	102	59	50
11.30.....	19	154	44	81	46	45	72	109	84	70
<i>p. m.</i>										
12.30.....	24	154	54	104	72	54	79	120	99	84
1.30.....	21	154	69	120	97	68	82	120	102	90
2.30.....	23	161	80	127	104	77	88	127	108	90
3.30.....	23	160	84	117	90	73	87	129	111	94
4.00.....	23	156	90.5	118	104	81	90.5	126	111	91

NOTES.

Air regulator about half open. Normal distance between louver boards, 1½ inches. Compartment regulator near heating box one-third open until 3 p. m. At that time opened to one-half. Other compartment regulator wide open.

Immediately after the 9.30 a. m. reading, the charging of the compartments was begun. Compartment near heating box filled at 10.15 a. m. Other compartment filled at 10 a. m.

At 3 p. m. contents were inspected and thawing estimated as 90 per cent completed.

At 4 p. m. contents were inspected thoroughly and found to be 100 per cent thawed. Test discontinued at 4 p. m.

Anemometer readings were made in the stack at 12 noon and 2 p. m. The volume of air passing out at 12 m. was 191 cubic feet per minute and at 2 p. m. was 209 cubic feet per minute.

The average outside temperature for the day was 21° F., the air being cold enough for a practical test. As one compartment was open 30 minutes and the other 45 minutes, the air within the thaw house was cooled practically to that of the outside air, and the temperature within at "W" and "E" did not reach the usual 90° F. until 4 p. m. This was unnecessary, as all the explosive was thawed before 4 p. m. The maximum temperature of the air entering the compartments, recorded by the thermometer at place of 5 at 3.30 p. m., was 129° F., which is within the safe maximum temperature recommended by the bureau. It should be noted, however, that this temperature should not prevail for long intervals of time, as mentioned elsewhere in this paper; and, furthermore, when explosives have become thawed the temperature maintained within the house should be reduced. As the temperatures at "E" were constantly greater than those at "W," it was necessary at 3 p. m. that the compartment regulator of the compartment nearest the heating box be opened from one-third to one-half, which brought both readings to 90.5° F. at 4 p. m.

The high temperatures (149° F. to 161° F.) recorded within the heating box indicate how dangerous is the practice of placing steam coils within thaw houses or magazines. Consequently the practice can not be recommended.

BILL OF MATERIALS.

For the benefit of those who may be particularly interested in such data the following bill of materials used in the Bureau of Mines thaw house is presented:

Lumber.

2 pieces of yellow-pine lumber, 6 inches by 6 inches by 12 feet.
 2 pieces of yellow-pine lumber, 2 inches by 6 inches by 16 feet.
 12 pieces of yellow-pine lumber, 2 inches by 6 inches by 14 feet.
 8 pieces of yellow-pine lumber, 2 inches by 4 inches by 14 feet.
 850 board feet of yellow-pine matched flooring, 1 inch by 6 inches by 12 feet.
 180 board feet of yellow-pine matched flooring, 2 inches by 6 inches by 16 feet.
 6 pieces of white pine, 1½ inches by 12 inches by 16 feet.
 Cost, \$40.26.

Hardware.

400 square feet of No. 24 galvanized flat iron.
 3 pieces of galvanized flat iron, 8 feet by 24 inches.
 2 pieces of corrugated galvanized iron, standard 24-gage, 8 feet long.
 45 1-inch return-pipe bends.
 266 feet of 1-inch pipe.
 2 1-inch, plain, 5-branch tees.
 94 square feet of brass wire cloth, 19-gage wire, 30 inches wide, 4 meshes per inch.
 Nails.
 2 pairs of No. 124 Coburn trolley hangers.
 12 feet of No. 3 track.
 4 end brackets and 2 center brackets.
 Cost, \$65.02.

Concrete.

5 barrels of cement.
 4 cubic yards of sand.
 2 cubic yards of gravel.
 Cost, \$10.61.
 Total cost, \$115.89.

HOT-WATER HEAT.

In some cases it may be more convenient to use hot water as a means of heating the air which enters a thaw house. Hot-water heating requires a greater radiating surface than steam heating. If a thaw house must be isolated from any auxiliary source of steam or hot water a small hot-water heater may be installed in accordance with the well-established principles of hot-water heating. The heater should, however, be installed in a separate compartment, located at least 4 yards from the thaw house.

ELECTRIC HEATERS.

Electric heaters are known to be less efficient and less safe than low-pressure steam or hot-water coils for thawing explosives; nevertheless in certain work electricity is the only available source of heat. With this consideration in view an investigation of the heating of thaw houses by electricity was undertaken by the authors in cooperation with H. H. Clark, electrical engineer of the bureau. The dangers encountered are given in order to promote greater safety in thawing explosives when electric heating is the only alternative. In the tests the steam coils of the bureau's experimental thaw house were replaced with electrical means of heating. The conclusions drawn from the results of the tests are as follows:

Electricity will, under certain conditions, produce sparks and flashes sufficient to ignite explosives or to cause fires that may result in such ignition. It is therefore necessary to select and install heating devices, connections, and circuits with reference to the special service which they are to perform. By far the most unattractive feature of electric heating is the probability of obtaining undesirably high temperatures in the immediate vicinity of the source of heat, and also the certainty that there is almost no limit to the temperature which such sources of heat will attain if the emission or diffusion of heat from them is sufficiently restricted.

Low-pressure steam or hot-water coils and electric heaters have characteristics that are exactly opposite. The rate at which steam coils give up heat is variable, depending upon conditions, whereas the rate at which electric coils give up heat is constant.

The temperature of steam coils can not exceed a certain maximum, which depends upon the pressure of the steam used, regardless of radiation and convection. There is, however, almost no limit to the temperature that may be attained by an electric heater, and its maximum temperature depends entirely upon those factors that affect the emission or diffusion of heat from the heaters. In this instance the most prominent are the weight of air passed per minute, its temperature, and its specific heat; the mechanical design of the heaters must also be considered.

From the foregoing, it is evident that low-pressure or hot-water coils are better adapted for the purpose under discussion, and that the operation of electrical heaters in connection with thaw houses requires a great deal of attention.

An increase in the temperature of the air surrounding a thaw house temporarily reduces the loss of heat from the house both by lessening the amount of heat transferred through the house walls and by decreasing the amount of air circulating through the house. A reduction in the rate at which heat leaves the house must result

in an increased temperature within the house. Since electric heaters deliver a constant amount of heat, if the temperature outside rises, some of the heaters should be switched out of service in order to keep the temperature inside from exceeding a safe value. This value might be exceeded if the temperature outside increased more than 10° F.

In the experimental thaw house of the bureau about 7 kilowatts of energy are required to maintain an average temperature of 90° F. within the thaw house when the temperature of the air outside is 0° F., whereas only 2 kilowatts, or thereabouts, is required when the temperature of the outside air is 55° F. Therefore, heaters must be provided that have a maximum capacity of 7 kilowatts, a minimum capacity of 2 kilowatts, and several steps between these values to take care of intermediate temperatures. A good combination is one heater of 2-kilowatt capacity and five heaters of 1-kilowatt capacity each.

The compartment in which the heaters are installed should be built entirely of noncombustible material. Each heater should be provided with a switch and fuses located upon the outside of the heater compartment. The heater should be fused as low as possible, and both switches and fuses should be carefully installed and protected from injury.

The heaters should be designed with large radiating surfaces so that the difference between their temperature and the average temperature of the air in the heating compartment may be as small as possible. It is recommended that the heaters be made up of units, each unit consisting of a single layer of uninsulated resistance wire wound upon a porcelain tube. The wire should be wound in a spiral groove or should be covered with an insulating enamel or equivalent substance. The units should be mounted upon an iron framework, from which they should be thoroughly insulated.

There should be as few connections as possible, and these should be made with great thoroughness. If solder is used, its melting point should be not less than 300° F. Only flame-proof insulated wire should be used for the leads or for any connection.

The voltage supply should be not higher than 250 volts, preferably not higher than 110 volts.

In thaw houses heated by electrical means, several thermometers should be installed, one of which should be in the heating box between the heaters and the opening through which the heated air enters the house.

Unless the foregoing suggestions can be followed and careful attention given to the operation of this type of thaw house while in service, recommendation is made that electricity be not used for thawing explosives.

PUBLICATIONS ON MINE ACCIDENTS AND TESTS OF EXPLOSIVES.

The following Bureau of Mines publications may be obtained free by applying to the Director, Bureau of Mines, Washington, D. C.

BULLETIN 10. The use of permissible explosives, by J. J. Rutledge and Clarence Hall. 1912. 34 pp., 5 pls.

BULLETIN 15. Investigations of explosives used in coal mines, by Clarence Hall, W. C. Snelling, and S. P. Howell, with a chapter on the natural gas used at Pittsburgh, by G. A. Burrell, and an introduction by C. E. Munroe. 1911. 197 pp., 7 pls.

BULLETIN 17. A primer on explosives for coal miners, by C. E. Munroe and Clarence Hall. 61 pp., 10 pls. Reprint of United States Geological Survey Bulletin 423.

BULLETIN 20. The explosibility of coal dust, by G. S. Rice, with chapters by J. C. W. Frazer, Axel Larsen, Frank Haas, and Carl Scholz. 204 pp., 14 pls. Reprint of United States Geological Survey Bulletin 425.

BULLETIN 26. Notes on explosive mine gases and dusts, by R. T. Chamberlin. 67 pp. Reprint of United States Geological Survey Bulletin 383.

TECHNICAL PAPER 4. The electrical section of the Bureau of Mines, its purpose and equipment, by H. H. Clark. 1911. 12 pp.

TECHNICAL PAPER 6. The rate of burning of fuse as influenced by temperature and pressure, by W. C. Snelling and W. C. Cope. 1911. 28 pp.

TECHNICAL PAPER 7. Investigation of fuse and miners' squibs, by Clarence Hall and S. P. Howell. 1911. 19 pp.

TECHNICAL PAPER 11. The use of mice and birds for detecting carbon monoxide after mine explosions and fires, by G. A. Burrell. 1912. 15 pp.

TECHNICAL PAPER 12. The behavior of nitroglycerin when heated, by W. O. Snelling and C. G. Storm. 1912. 14 pp.

TECHNICAL PAPER 13. Gas analysis as an aid in fighting mine fires, by G. A. Burrell and F. M. Seibert. 1912. 16 pp.

TECHNICAL PAPER 17. The effect of stemming on the efficiency of explosives, by W. O. Snelling and Clarence Hall. 1912. 14 pp.

MINERS' CIRCULAR 2. Permissible explosives tested prior to January 1, 1911, and precautions to be taken in their use, by Clarence Hall. 1911. 12 pp.

MINERS' CIRCULAR 3. Coal-dust explosions, by G. S. Rice. 1911. 22 pp.

MINERS' CIRCULAR 4. The use and care of mine-rescue breathing apparatus, by J. W. Paul. 1911. 24 pp.

MINERS' CIRCULAR 5. Electrical accidents in mines; their causes and preventions, by H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 1911. 10 pp., 3 pls.

MINERS' CIRCULAR 6. Permissible explosives tested prior to January 1, 1912, and precautions to be taken in their use, by Clarence Hall. 1912. 20 pp.

